National Aeronautics
and
Space Administration

Outer Solar System Chronology

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Project Objective

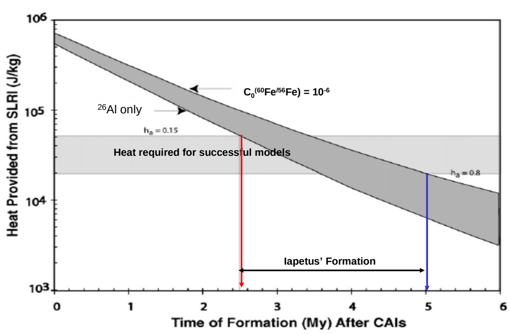
Understand the formation and evolution of the giant planets and their satellites and relate this to the inner solar system and extra-solar planetary systems.

Recent Results

We have suggested in a recent paper (Castillo-Rogez *et al.* 2007) that Saturn's moon Iapetus formed between 2.5 and 5 My after CAI production, and incorporated Short Lived Radioactive Isotopes (SLRI). Evidence that 26Al was present in the early history of the outer Solar system constrains the origin of this isotope, and as such the origin of the Solar system itself. This research also opens the door to coordinating the different chronological scales used by the different fields in astronomy and planetary science: cosmochemical, dynamical, geochronology, crater counting, and now satellite geophysics.

Project Description

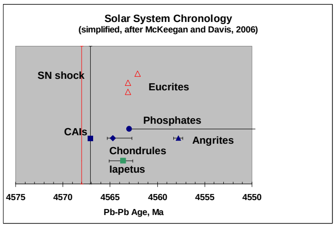
Recent astronomical observations suggest that the lifetime of gas and dust sufficient for making giant planets around Sun-like stars may be typically only two to five million years (Najita and Williams 2005; Calvet et al. 2005). Thus if short-lived radioactive isotopes (SLRI) with half-lives of less than 10 My were present in the circumstellar disk, they would be included in any planets formed. These isotopes would supply heat as they decayed, the most important being ^{26}Al and ^{60}Fe. The challenge is to find observations that test the validity of this scenario. In the Solar System, we believe that models of medium-sized satellites can be used for this purpose. Initial results suggest that they also yield constraints on the time of formation and chronology of the outer Solar system.

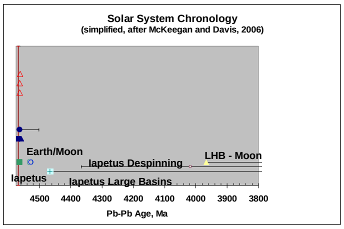


Castillo-Rogez et al. (2007) model Iapetus' thermal and dynamical evolution to explain its current synchronous rotation state and highly non-hydrostatic shape. Successful models require heat from SLRI's, implying rapid formation of the Saturn system between 2.5 and 5 My after CAI's.

If we accept the Pb–Pb age of CAIs measured by (Amelin et al. 2002) of 4567.2 ± 0.6 Ma, then the age of Iapetus is between ***4562.2 and 4564.7 Ma****.*

This time scale result provides an additional indication that giant planet formation was relatively rapid in our own Solar System and gives impetus to the further development and elaboration of the nucleated instability models for giant planet growth. Tying Iapetus' formation to Pb-Pb ages of meteorites provides a link between inner and outer solar system chronologies. The 'Nice' model for the dynamical evolution of the giant planets predicts a solar system-wide Late Heavy Bombardment (LHB) at 3900 Ma (Gomes et al., 2005). In our models for Iapetus, the satellite's crust would have been thick enough to record evidence of this event, and Iapetus' numerous large impact basins provide support for this scenario.





Benefits to NASA and JPL (or significance of results)

This project is directly related to NASA and JPL's goals of understanding the formation and evolution of our own and other planetary systems. It provides links between results from astrophysics missions such as Spitzer and planetary missions such as Cassini and proposed future missions to the outer solar system and icy satellites.

Publications

Amelin *et al.,* 2002. Science 297, 1678–1683, Calvet *et al.,* 2005. ApJ 630, 185, Castillo-Rogez *et al.,* 2007. Icarus doi:10.1016/j.icarus.2007.02.018, R. Gomes *et al.,* 2005. *Nature* 435 (7041), 466-469, McKeegan and Davis, Treatise on Geochemistry, Vol 1, 2006 ed, Najita and Williams, 2005. Astrophys. J. 635, 625–635